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14. ABSTRACT While a successful counter-insurgency operation is dominated by political, diplomatic, informational, economic, and social components, it is often necessary to conduct police or military direct action to remove irreconcilable elements from the population. If such operations are not carefully administered and synchronized, they can have a counterproductive effect on the remainder of the population. This study examines the potential impacts of such direct action operations on the population in the struggle to gain their support and foster the legitimacy of the government. While limited in scope, the study identifies three relevant parameters that are within the control of the operational commander. The commander can devote assets to develop intelligence to provide a sufficient level of fidelity to prevent adverse actions. Closely linked to intelligence, the commander can establish a suitable threshold for operations. Finally, the commander can adjust his assets to raise or lower his capacity to develop and execute the direct action component of his operational concept. This study presents a mathematical model that identifies some of the relationships between these parameters, and offers possible measures of performance and effectiveness. Through proper monitoring of these measures and continuous reassessment of the relevant parameters, the direct action component can effectively remove irreconcilable elements and support the greater objectives of providing a secure environment for prosperity, a supportive populace, and a legitimate and capable government.					
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**NAVAL WAR COLLEGE
Newport, RI**

Modeling the Effects of Direct Action Operations on an Insurgent Population

by

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Major, US Army

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature:_____

23 April 2008

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Abstract

While a successful counter-insurgency operation is dominated by political, diplomatic, informational, economic, and social components, it is often necessary to conduct police or military direct action to remove irreconcilable elements from the population. If such operations are not carefully administered and synchronized, they can have a counterproductive effect on the remainder of the population. This study examines the potential impacts of such direct action operations on the population in the struggle to gain their support and foster the legitimacy of the government. While limited in scope, the study identifies three relevant parameters that are within the control of the operational commander. The commander can devote assets to develop intelligence to provide a sufficient level of fidelity to prevent adverse actions. Closely linked to intelligence, the commander can establish a suitable threshold for operations. Finally, the commander can adjust his assets to raise or lower his capacity to develop and execute the direct action component of his operational concept. This study presents a mathematical model that identifies some of the relationships between these parameters, and offers possible measures of performance and effectiveness. Through proper monitoring of these measures and continuous reassessment of the relevant parameters, the direct action component can effectively remove irreconcilable elements and support the greater objectives of providing a secure environment for prosperity, a supportive populace, and a legitimate and capable government.

INTRODUCTION

An insurgency is a struggle between several groups to gain or maintain political control. Successful defeat of an insurgency requires the integrated and sustained application of all diplomatic, informational, military, and economic tools available to the counter-insurgent. While the struggle will be ultimately won or lost through non-military means, the select application of precise military power is an essential supporting element. The military tool can safeguard infrastructure, protect the population, secure the environment, and remove irreconcilable elements of the insurgency. An over-reliance on direct military action can have a detrimental effect on the population, while a failure to remove irreconcilable elements can undermine the perceived legitimacy of the government¹. At the operational level of war, the counter-insurgent military commander must achieve the proper balance of direct military action in order to support the decisive political efforts to defeat the insurgency.

Warfare at the operational level is more art than science. This is arguably most true in insurgency warfare. It is not possible to remove the human dimension from war, nor is it possible to achieve victory without looking at all aspects of the system as a whole. However, modeling of select elements of insurgency warfare can provide insight to the operational commander that can assist in development, implementation, and assessment of an operational concept². When applied to the role of direct action operations to kill or capture select elements of an insurgent force, a conceptual model can provide insight into the roles and interrelationships between key parameters. Through proper understanding and control of key parameters in the application of direct action, the operational commander can constructively influence the outcome of an insurgency.

This study presents a model for the struggle to gain the support of a population through the controlled and deliberate application of direct action to kill or capture irreconcilable elements of the insurgency. The study is limited in scope, and only explicitly addresses parameters that are involved in direct action. This limits the scope of the model, and is not intended to downplay the key role of non-kinetic elements of counter-insurgency warfare in any way.

POPULATION MODEL

Based on current operational theory, the population is a decisive point in the operational battle³. Support of the population is critical to the success of both the insurgent and counterinsurgent. The population is composed of individuals who possess a spectrum of attitudes and motivations. The Army's current Counterinsurgency Manual recognizes that the population includes extremist supporters of both the insurgents and the legitimate government, with a large majority of the population falling in between⁴. A more flexible population model, used in this study, is shown in Figure 1⁵. In this model, each member of the population is assigned a value from zero to ten, representing their "Disposition"⁶ towards the insurgency and the legitimate government. Superimposed on this continuum is the distribution of the population, representing how many members of the population lie at each point on the spectrum. In a stable society, this distribution would be weighted heavily towards the lower end of the scale, with just a small fringe element that opposes the government. In an insurgency, there can be a significant portion of the population that actively opposes the government, and a large portion that is either passively or actively supportive of the insurgent extremists. The objective of the counterinsurgent is to push the distribution back towards the lower end of the scale. Victory is not assured merely by

maintaining the neutrality of the population. The counterinsurgent must actively gain at least passive support from much of the populace in order to succeed⁷. This model assumes that extremists at the far right end of the scale are willing to organize and conduct violent acts in support of the insurgency.

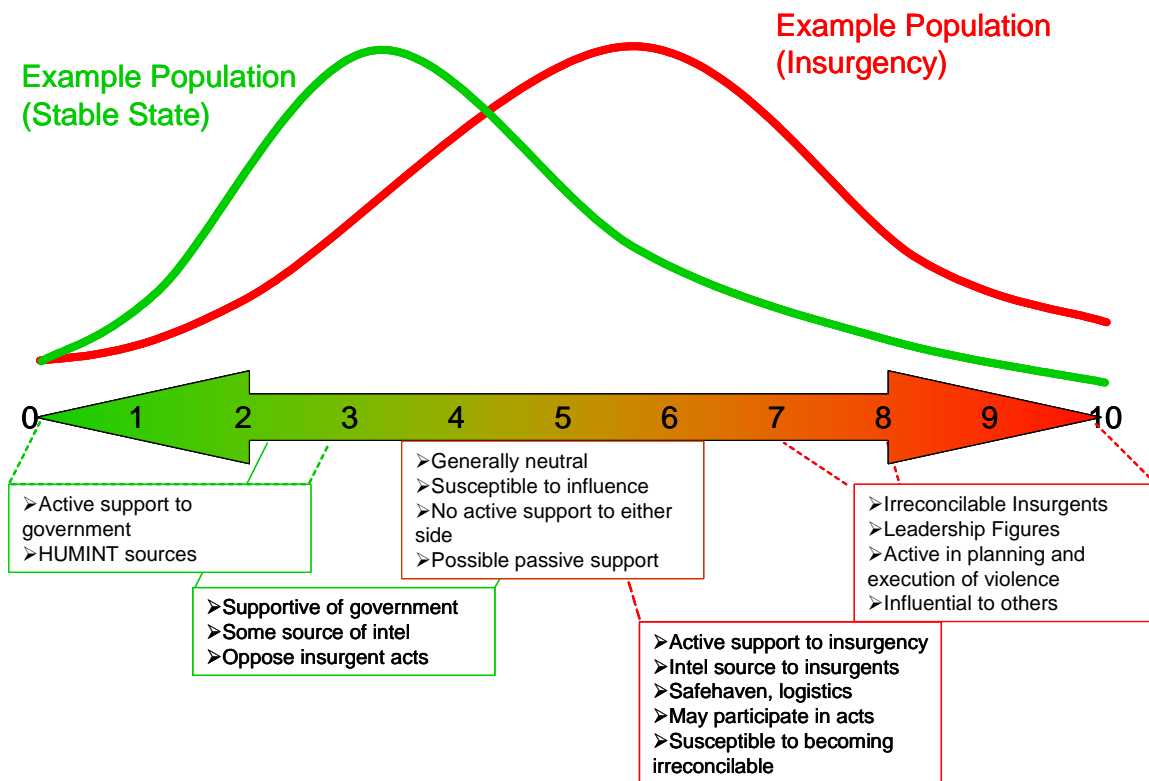


Figure 1. *Spectrum of personal Dispositions within a sample population (on a scale of zero to ten). Those near the right side of the scale are strongly supportive of the insurgency, while those at the far left strongly back the government. The majority of the population lies in the middle, weakly supportive of either side. It is this segment of the population that is most susceptible to influence, coercion, intimidation, and reconciliation.*

Extremists at the lower end of the scale are dedicated to the sovereign government, and will actively provide support and intelligence to counter-insurgent forces. Those in the middle of the scale will neither actively support insurgents, nor volunteer useful information to the government forces. Most importantly, those elements in the middle of the scale are susceptible to be influenced towards either extreme based upon the actions of the insurgents

and counter-insurgents, and based upon the perceived legitimacy of both elements. The population can also influence some mild insurgent supporters to be more moderate in their views. However, extremists towards the right end of the scale cannot be easily dissuaded in their views. These represent the irreconcilable insurgents that must be targeted by direct police or military action.

The counter-insurgent targets these irreconcilable insurgents based on intelligence. Because the population is the single greatest source of intelligence in an insurgency, the level of available intelligence is assumed in the model to depend upon the number of passive and active government supporters at the left end of the scale. When the insurgency gains momentum and the population begins to shift towards supporting the insurgents, the intelligence available to the counter-insurgent will drop.

Based on intelligence, the counter-insurgent conducts action against members of the population that he perceives to be the most threatening and irreconcilable elements. If his intelligence is of good quality, the counterinsurgent will remove the insurgent successfully. If the intelligence is poor, the counter-insurgent risks killing or capturing a potentially neutral (or even supportive) member of the population. This action not only removes a potential supporter from the population, it also has severe repercussions among the remainder of the population⁸. Collateral damage, whether resulting from faulty intelligence or from indiscriminate action, will lead to an overall increase in support for the insurgency⁹.

A failure of the government to act against insurgent violence also has a counterproductive effect on the counterinsurgent efforts. When insurgents operate freely and undermine the perceived legitimacy of the government, the population will slowly withdraw

their support for the government¹⁰. Therefore, a failure of the counterinsurgent to remove irreconcilable elements has negative consequences.

DIRECT ACTION PARAMETERS

The decision to use direct action to remove select elements of the population through police or military action is based upon a number of parameters that are subject to some degree of control by the counter-insurgent operational commander¹¹.

The parameter “Intelligence”¹² describes the level of fidelity of the information that the counter-insurgent has regarding each element of the population. With perfect intelligence, the counter-insurgent would know exactly where along the disposition spectrum the individual lies. With less than perfect intelligence, there will be some error between the individual’s perceived disposition and his true disposition. The initial intelligence baseline is determined by a variety of factors, including: initial human intelligence (HUMINT) network based on existing supporters¹³, level of technical collection means, and the analytic capabilities at the operational and tactical levels. As a commander could plausibly improve the level of intelligence on a given target with further effort, Intelligence could also be interpreted as the level of fidelity required by the commander before making a decision to act against a given target. As a practical matter, intelligence comes at a cost and the commander does not have complete control over this parameter. In addition, as the insurgency progresses the value of Intelligence will be modified based upon the number of government supporters in the population.

The parameter “Threshold” defines the limit of Disposition at which the commander would initiate direct action. The Threshold is the lowest perceived Disposition against which the commander would act. Threshold sets the lower bound for direct action. For example,

with a threshold of seven, the counter-insurgent will attempt to kill or capture any identified insurgent with a perceived Disposition of seven or greater. The commander has complete control over the choice of Threshold.

“Capacity”¹⁴ describes the counter-insurgent’s ability to cover the targeted population area. When capacity is small, the counter-insurgent is only capable of identifying, locating, or actioning a limited number of targets during a given time period. As Capacity grows, the counter-insurgent is able to look at more of the population during a given period. Capacity is roughly analogous to the amount of area to which the operational commander has dedicated forces or collection assets. Due to competing requirements, access problems, and political constraints, Capacity is not unlimited and a decision to increase Capacity would likely be a last resort.

These three parameters are clearly inter-related. Some combinations are costly to the counter-insurgent, while others require a trade-off with competing missions. The analysis below will highlight how the counterinsurgent operational commander can control these variables to contribute to the defeat of an insurgency. Several examples will also demonstrate where a poor choice of operational parameters can be detrimental to counterinsurgency efforts.

IMPLEMENTATION OF THE MODEL

A detailed description of the model used for this study is included in Appendix A. The population is modeled on a checkerboard grid, with each cell representing one element of the population with a single Disposition from zero to ten, indicating his support to the insurgency or the government (each “element” could be a single person, or a homogenous social group with a shared disposition). At the beginning of the simulation, the dispositions

of each cell are randomly arrayed according to the distribution of the population¹⁵. Figure 2A shows an example of a 10 x 10 grid with an initially distributed population. Each cell has up to eight adjacent “neighbors” with which it interacts. These neighbors are not geographical neighbors, but represent associations or social interactions.

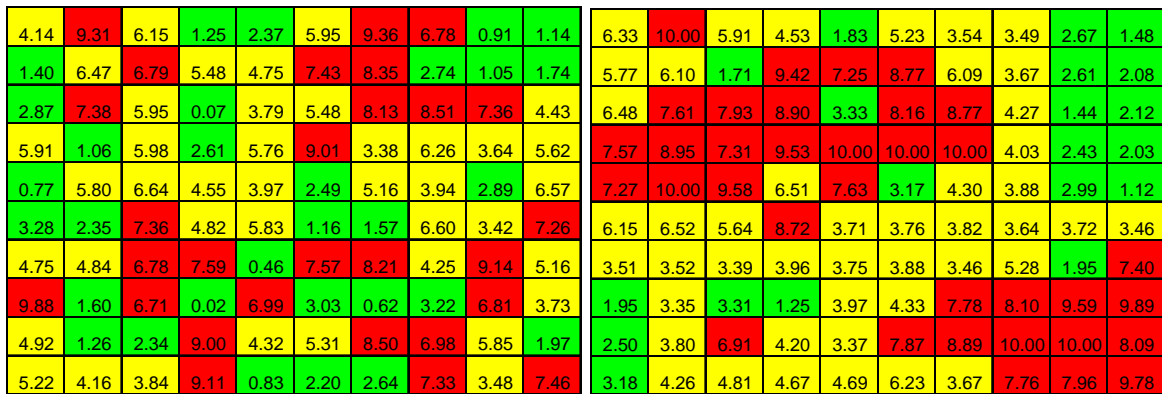


Figure 2A. Initial distribution.

Figure 2B. Distribution after 100 time steps.

In each figure, cells green cells have Dispositions between 0-3.3, representing support for the government. Red cells have Dispositions between 6.7-10, and support the insurgency. Yellow cells represent the middle third of the population. Areas of insurgent and counterinsurgent cells begin to emerge after 100 time steps, as seen by the grouping of red and green cells in Figure 2B.

At the beginning of each iteration, the counterinsurgent commander defines his operational concept for direct action. In this concept, he describes the intent for the development of Intelligence and the Threshold that he feels is suitable for direct action. He also determines the Capacity available for direct action. While a true operational concept would include significantly more guidance in other aspects of the counterinsurgency effort, and would likely not include quantitative representations of the parameters (Intelligence, Threshold, and Capacity), these values represent the operational concept for this model.

At each time step in the model, the counter-insurgent identifies, analyzes, and actions individual targets within the commander’s guidance. The counter-insurgent “develops” targets by selecting cells at random and evaluating their Dispositions¹⁶. If the perceived

Disposition is greater than the Threshold (T), then the target is removed from the grid. Note that if the Intelligence is less than perfect, the counter-insurgent may be inadvertently removing cells that lie below the specified Threshold. After all cells have been evaluated (the actual number of cells evaluated each step is a function of the specified Capacity), then the effects on the population are analyzed.

For every action conducted, there is a negative reaction by the neighboring cells. Each neighboring cell's Disposition increases as a result of "collateral damage" from the operation. If the removed cell was an irreconcilable insurgent, then this collateral damage is minimal¹⁷. In addition, the action is beneficial to the counterinsurgent because a cell with a large Disposition is removed from the population. If, however, the removed cell was neutral or supportive of the government, then the neighboring cells may shift significantly to the right on the scale of Disposition. This collateral damage effect also includes the negative impact of propaganda and potential legal issues¹⁸. After adjusting for collateral damage, the population as a whole reacts to the continued presence of insurgents and insurgent violence. This adjustment represents the population's waning confidence in the capability of the government to provide for their local security¹⁹.

Finally, the Disposition of each cell is adjusted based on the Dispositions of its eight neighbors. This represents the well-established influence of members of the population on each other²⁰. If a neutral cell is surrounded by several insurgent cells, the neutral cell will increase in Disposition. Conversely, a group of government-supporting cells can decrease the Disposition of a neighboring cell. Neutral cells are more easily influenced by extremist cells (of either extreme) than are cells that lie at the ends of the Disposition spectrum. As

successive time steps progress, a given cell can propagate its influence further from its original location^{21,22}.

As a result of implementation of the counter-insurgent's operational concept and the various interactions described above, the overall distribution of the population will change. When the operational concept is sound, extremist insurgents will be removed from the population and the overall disposition of the population will become more favorable to the government. If the operational parameters represent an unsuccessful concept, the population will gradually become more supportive of the insurgency.

ANALYSIS

Figure 2B shows the checkerboard after 100 time steps. The initially random distribution of the population has become a mosaic of neutral members with bands of pro-government supporters and isolated pockets of insurgent resistance. Based upon the operational parameters, the pockets of resistance will either grow or fade based upon changes to the neutral population. The overall progress of the insurgency can be represented by the average Disposition of all cells. Figure 3 shows three different insurgencies that all began with the same initial population, but with different choices of operational parameters.

Curve 3A shows a consistent decrease in overall Disposition with time, representing the elimination of insurgents and a positive (i.e., supportive of the government) impact on the neutral population. This iteration began with a high value of initial Intelligence and an appropriate Threshold. As expected, violence drops as high-level insurgents are removed and passive supporters are persuaded by their neighbors to be less extreme in their views. The level of intelligence also increases as more of the population becomes supportive of the

counter-insurgent. This choice of operational parameters contributes to the overall counterinsurgency effort, and is considered successful.

Curve 3B shows an insurgency that remains fairly constant. There are frequent small spikes and drops in overall Disposition. Counterinsurgent efforts are being offset by detrimental collateral damage, or the operational concept is sound but is simply not enough to tip the scales in favor of the government.

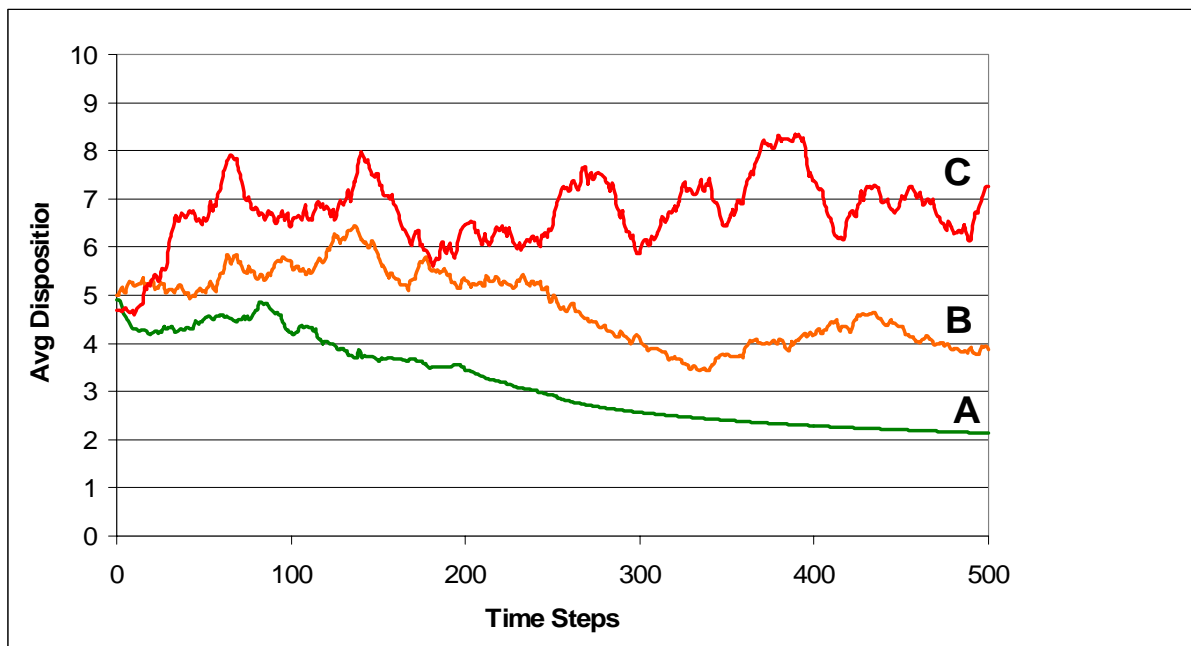


Figure 3. Evolution of three insurgencies with varying levels of success. Insurgency A (in green) leads to a steady decrease in support for the insurgency. Insurgency C (red) shows an insurgency that grows in strength with time. Insurgency B remains undetermined, and represents maintenance of the status quo (3A: $I = 85$, $T = 7.25$, $C = 10$; 3B: $I = 70$, $T = 7.1$, $C = 10$; 3C: $I = 65$, $T = 6.5$, $C = 10$).

Curve 3C shows an operational concept that is being counter-productive to the overall counterinsurgency effort. With relatively poor intelligence and an inappropriately low Threshold, the counter-insurgent is frequently killing or capturing neutral members of the population. Each of these actions removes potential supporters, contributes collateral damage to local cells, and leads to an overall rise in violence that further deteriorates public

support. The gradual loss of a supportive populace further decreases the available intelligence and compounds the problem. Curve 3C clearly shows that this operational concept was unsuccessful²³.

With an understanding of how the various operational parameters can affect the population, it is possible to model multiple insurgencies across the range of parametric values. Two key relationships merit more in-depth analysis. The first is the relationship between Intelligence and Threshold, and the other is the relationship between Capacity and the size of the insurgency.

Better intelligence is clearly an advantage to the counter-insurgent. Improved intelligence reduces collateral damage and prevents the inadvertent removal of neutral persons. With a fixed level of intelligence, a low Threshold would be expected to result in more overall kill/capture operations during a given time period than a high Threshold. The model confirms this observation. If the Intelligence level is decreased, the counter-insurgent still actions roughly the same number of targets each cycle. However, due to the uncertainty of the Intelligence, a larger fraction of those targets actually had true Dispositions below the stated Threshold. This is the source of the excessive collateral damage. This fact also presents a possible Measure of Performance (MOP) for use by the operational commander. Following each direct action, the exploitation and debriefing process may give an improved picture of where the detained individual actually stood on the scale of Disposition. Comparing this to the perceived Disposition prior to the operation could provide a measure of intelligence quality. Although in reality this would be difficult to do quantitatively, even a qualitative objective assessment would be useful.

Given that higher Intelligence fidelity is always better, the commander must choose a suitable Threshold value. When the Threshold is too high, the counter-insurgent leaves some irreconcilable elements of the insurgency in the population. In addition to conducting violent acts, these remaining insurgents can influence neighboring cells to become more extreme (this could be analogous to coercion, intimidation, or persuasion). These un-actioned insurgents are beyond the ability of the local populace to control by mere influence. In the model, a high Threshold manifests itself as a smooth but accelerating increase in the overall average Disposition (see Figure 4A). The population distribution slowly progresses to the right, with corresponding increases in violence and losses in intelligence.

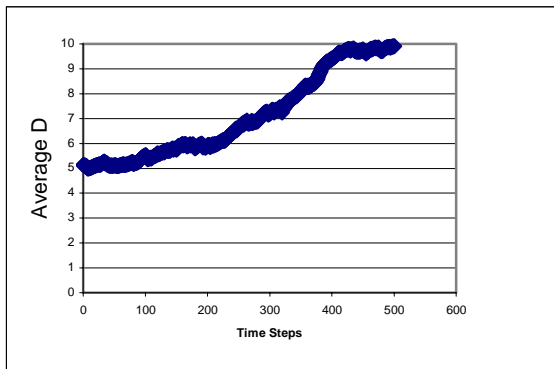


Figure 4A. *Threshold set too high.*

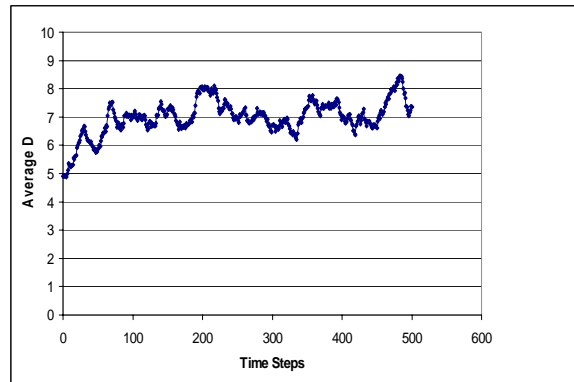


Figure 4B. *Threshold set too low.*

The vertical axis shows the Average Disposition of all the cells in the model. The horizontal axis shows time steps, representing the evolution of the insurgency over time.

In contrast, the Threshold can also be too low. Even with near-perfect intelligence, a low Threshold can result in excessive collateral damage. When this happens, the effect on the neighboring cells leads to the development of small pockets of anti-government resistance. Successive removal of low-Disposition cells, especially in the same region or closely spaced in time, leads to a series of rapid spikes in overall Disposition (see Figure 4B). Many of the low-Disposition targets that were actioned by military forces could have likely been influenced by neighboring cells instead. In other words, the long-term negative effects

of removing “reconcilable” militants by direct action may have outweighed the immediate and localized benefits of the action.

Figure 5 shows the results of multiple runs with various Threshold values. Each curve represents a different value of initial Intelligence. The vertical axis shows the average Disposition at the end of 500 time steps, and is a possible Measure of Effectiveness (MOE). The minima in each curve shows the point where the overall Disposition of the population was at its lowest level, indicating the optimal Threshold for a given intelligence. A Threshold above or below the optimum value will result in a less favorable outcome for the counter-insurgent. Comparing the minima in the curves for different values of Intelligence reveals that the optimal Threshold drops as Intelligence is increased. The implication of this is that as intelligence improves, the operational commander can afford to pursue lower-Disposition targets with less risk of collateral damage. However, if these active or passive insurgents can be effectively dealt with through other means (coercion, reconciliation, or non-kinetic means) this would be overall beneficial to the counter-insurgent’s efforts.

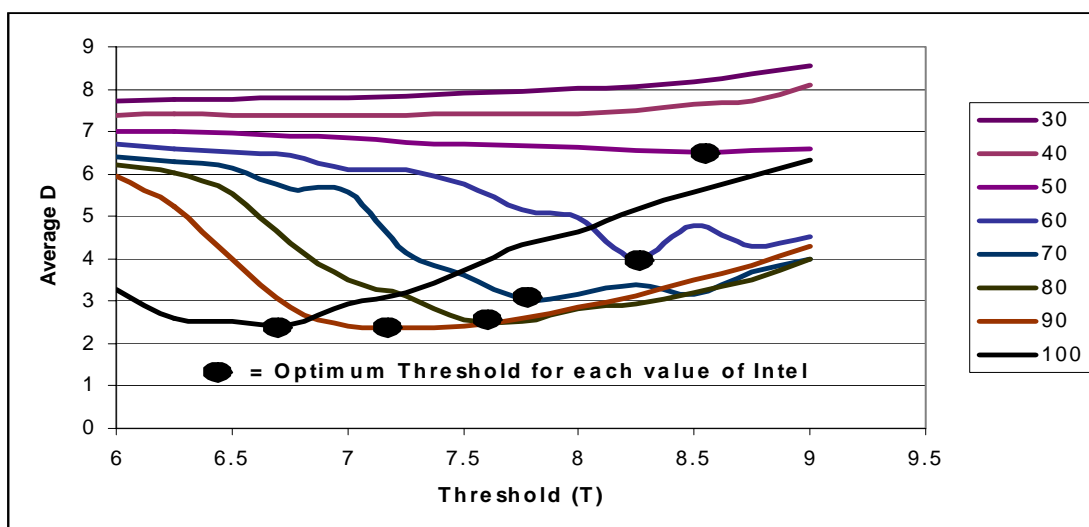


Figure 5. Average Disposition as a function of Threshold for various levels of Intelligence. As Intelligence improves, the optimum value of Threshold becomes lower (indicated by the black dots at the minima of the curves). Each curve represents a different value of Intelligence.

It is not realistic to believe that a counter-insurgent commander would be able to quantify such values as Threshold, Intelligence, or average Disposition. Any attempt to turn such social judgments into numerical measures would likely be counter-productive. However, it is useful to understand the relationship between Intelligence and Threshold, and to realize that certain combinations of these parameters may lead to positive results, while other choices could be detrimental. Figure 6 shows a map of Intelligence versus Threshold. The green region in the center indicates combinations of these parameters that were observed in the model to lead to success. Even without quantitative information available, it is useful to note that while operating at Point A in Figure 6 the counter-insurgent is succeeding. However, if conditions change and intelligence capability diminishes, the operating point may move to point B. At Point B, the Threshold is no longer appropriate and any direct action efforts may be counter-productive. As conditions in the operating environment change, the commander must re-assess his operational concept for direct action operations. In this example, he should raise his Threshold to move to Point C in the figure.

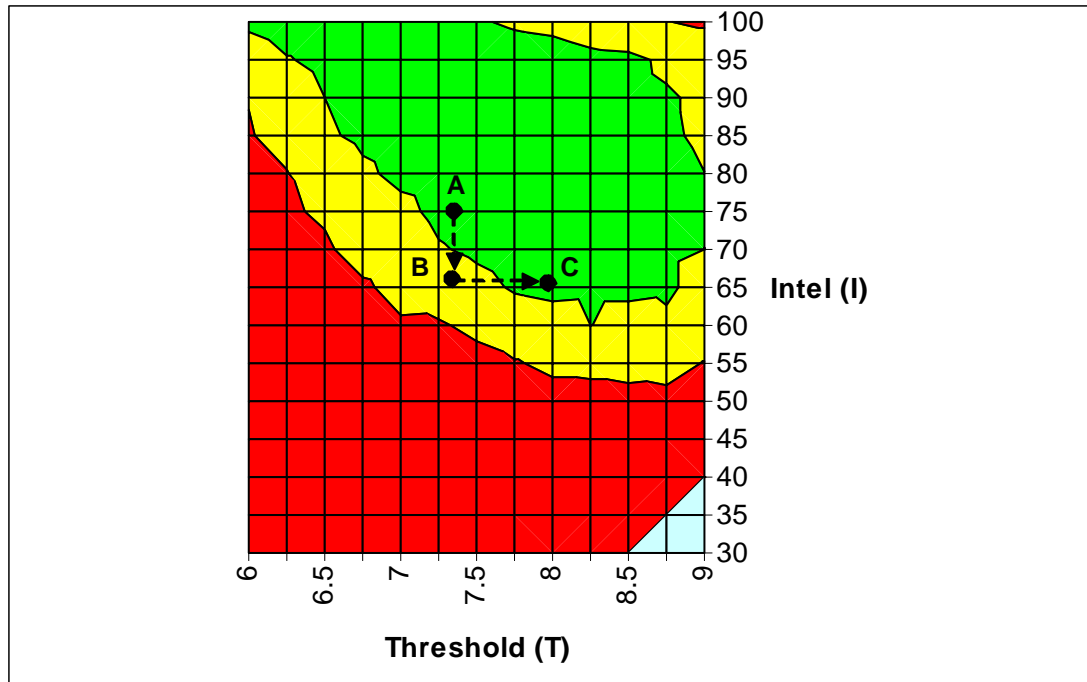


Figure 6. *Operating map of Intelligence and Threshold. The green zone represents the combination of parameters that generally leads to success for the counterinsurgent, while the red area generally leads to a growing insurgency.*

It seems intuitive that as the number and activity of insurgents increase, the capacity of the counter-insurgent to identify and action insurgents must increase. Figure 7 shows this effect, as the average Disposition is plotted against the Capacity for several different values of initial insurgency strength. At the lower end of the Capacity scale, Figure 7 does show that small increases in Capacity can provide a significant benefit for the counter-insurgent. Increasing Capacity could require committing an operational or strategic reserve, diverting troops from security missions, devoting additional intelligence assets, or spreading existing troops. All of these actions have associated costs.

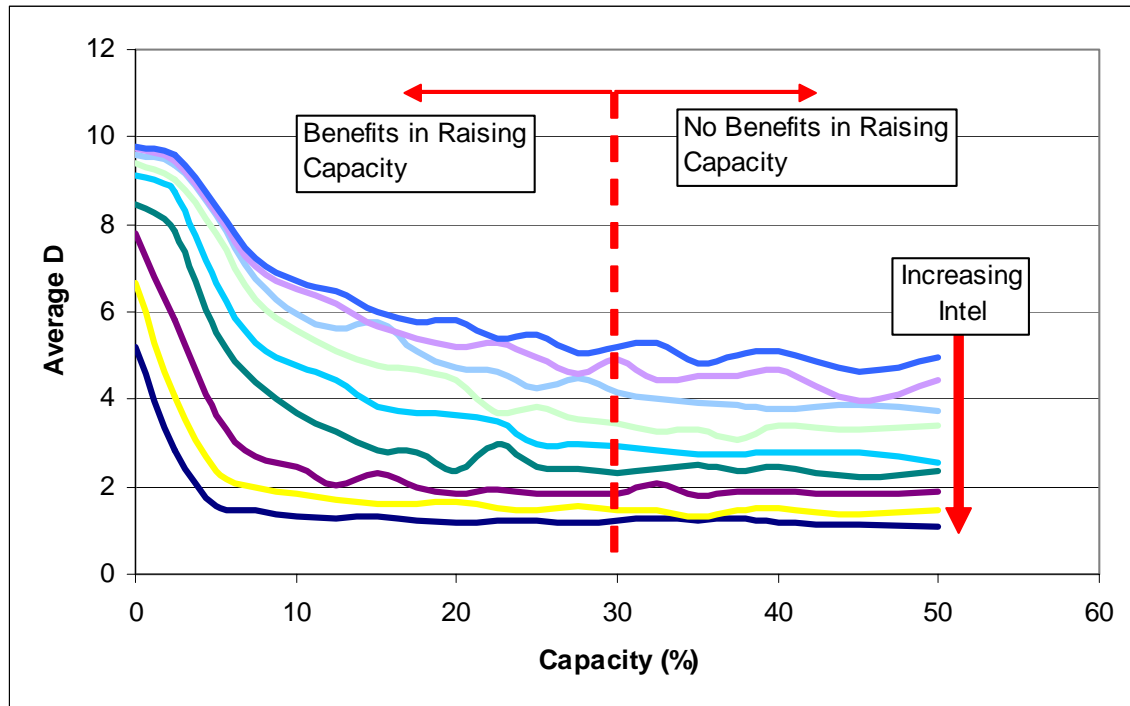


Figure 7. *Effects of changing Capacity. As Capacity grows from zero to 30%, the counterinsurgent can make significant gains, rapidly reducing the Average Disposition (shown on the vertical axis) of the population. After 30% Capacity, additional gains are minimal.*

Figure 8 shows what Capacity levels led to positive outcomes for various initial insurgent population levels. When operating at Point A in Figure 8, the counter-insurgent generally needs all the Capacity he is using. When insurgent levels are observed to drop down to Point B, the counter-insurgent commander is devoting excess Capacity to direct action and can free up these resources for other missions without a significant impact on kill/capture performance.

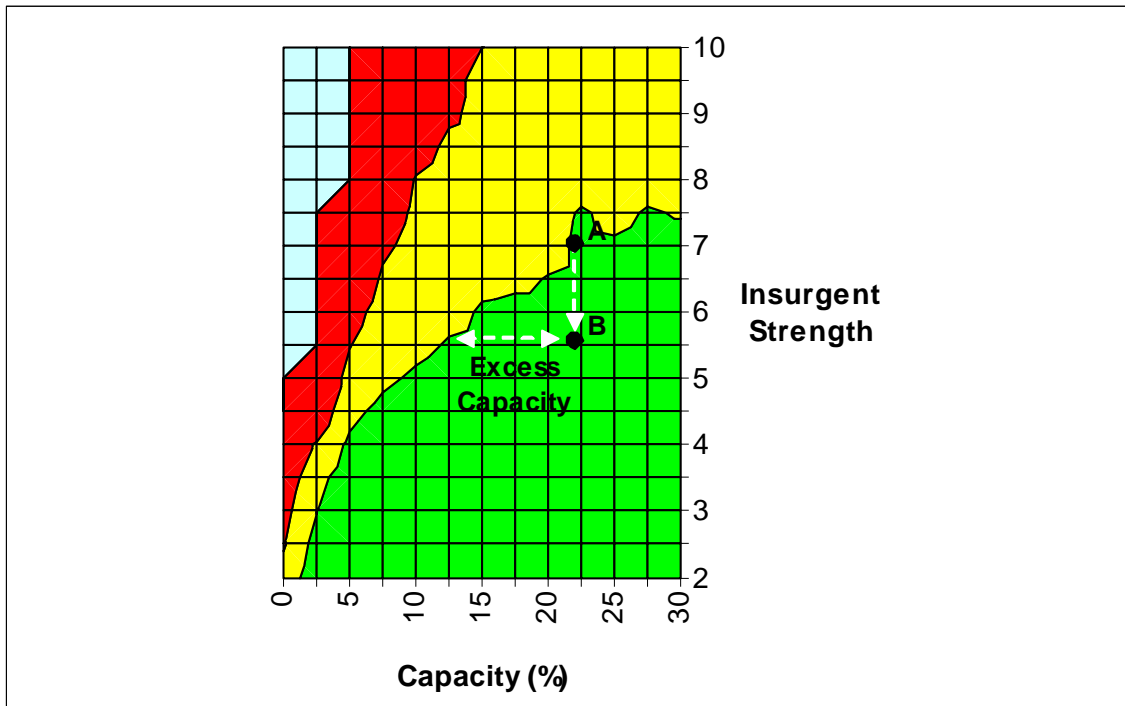


Figure 8. Operating map for Capacity and insurgent strength. The green zone represents the combination of parameters that generally leads to success for the counterinsurgent, while the red area generally leads to a growing insurgency.

Figure 9 shows the optimization of Intelligence, Threshold, and Capacity. Operating in the green area represents an operational concept that was generally successful in defeating the insurgency. Operations in the red were generally unsuccessful, while operating in the yellow area was indeterminate. Based on the results described above, Threshold is optimized for each value of intelligence, and an optimum value of Capacity is used for each insurgent strength level. Several conclusions can be drawn from this map. First, there exists a lower bound on intelligence below which there is little chance of having positive effects against the insurgency (approximately 50% in this chart). Secondly, it is apparent that when the insurgent strength exceeds a given value (approximately 8 in Figure 9), there is no operational concept that is likely to succeed—even with perfect Intelligence and maximum Capacity. These situations support the statement in FM 3-24 that “Sometimes doing nothing is the best reaction.”²⁴ The commander should direct maximum efforts to non-kinetic means

of reducing the insurgent population through security, information operations, political efforts, and economic and civil affairs projects. Another option is to reduce the “penalties” associated with direct action operations through increased use of local police forces, aggressive psychological operations and strategic communications, preemptive incident management and public affairs, and improving the precision of necessary direct action (at greater risk to the force).

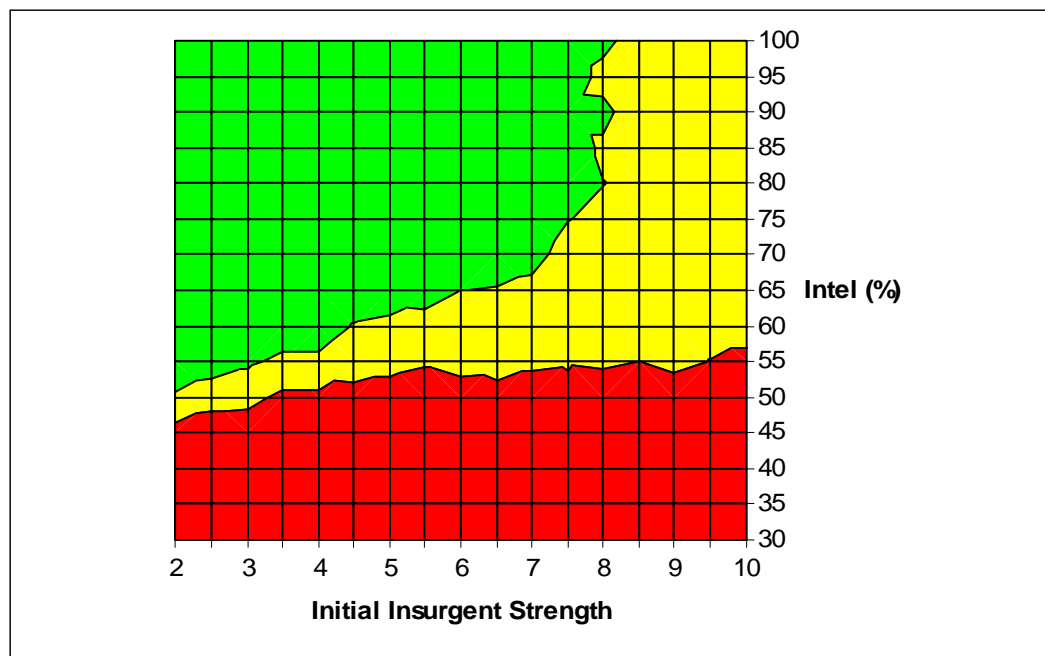


Figure 9. *Optimized operating map for all values of Intelligence and Insurgent Strength. The green zone represents the combination of parameters that can contribute to success. Within the red area, however, no combination of operational parameters led to a direct action operations that helped the overall counterinsurgency effort..*

The following example applies the observations above to a modeled insurgency that is initially is gaining strength (see Figure 10). After 100 time steps, the operational commander directs a re-assessment of the environment. The initial Intelligence was $I=80\%$ with a Threshold of $T=7.5$. After 100 time steps, the counterinsurgent commander observed a MOP of 76% (indicating the percentage of operations that removed an insurgent above the

stated Threshold). Levels of violence rose to 115% of their initial levels, while a population survey indicated a growth of 12% in the population of insurgent supporters²⁵.

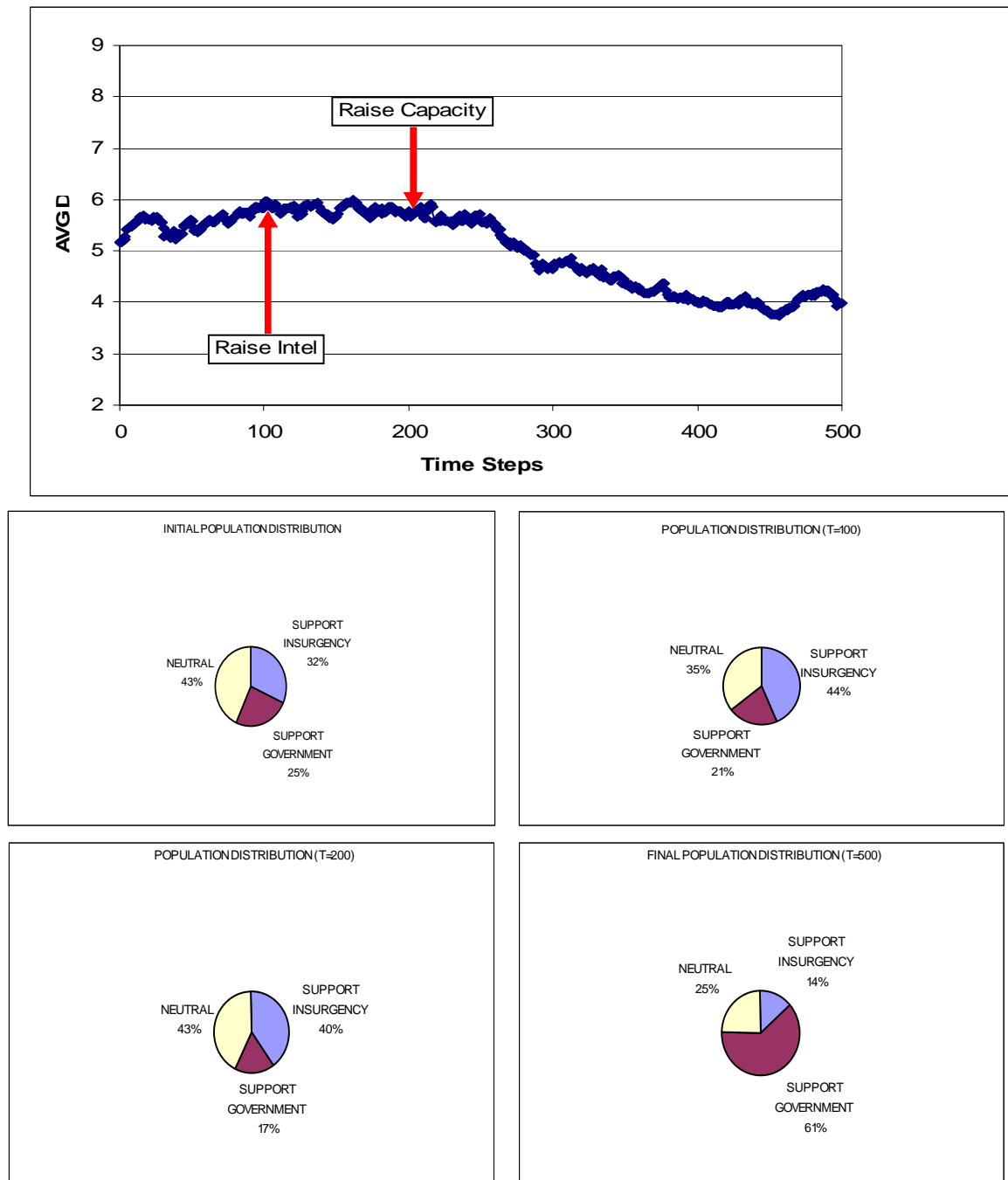


Figure 10. Evolution of insurgency (Example). Counter-insurgent made adjustments at $T=100$ and again at $T=200$ in response to an ever-increasing insurgency (represented by Average Disposition). Pie charts show the distribution of the population at several points in time.

Based on these results, the counterinsurgent raised the Intelligence value to 90% by increasing HUMINT Collection, dedicating additional technical collection assets to the search for irreconcilable insurgents, and raising the standard for the desired level of target fidelity. By T=200 violence levels had leveled out. The adjustment in intelligence assets had led to a MOP of 86%, indicating the concept was successful. Population data showed a moderate drop in insurgent support. Although the indicators did not indicate that the direct action operations were having an adverse impact on the population, the insurgency had become too widespread to be defeated at the current level of Capacity. In the current environment, the commander could not reasonably expect to improve his Intelligence level any further. The survey data indicated that the Threshold level was appropriate for the current Intelligence level. The operational commander redirected efforts and raised the Capacity from 5% to 15% while keeping the same Intelligence and Threshold levels. Over the next 300 time steps this new operational concept reduced violence levels to 76% of the baseline level. In addition, support for the government rose to 61% of the population, while insurgent support was reduced to just 14%. After this brief surge of efforts towards eliminating irreconcilable insurgents, the commander could consider reducing Capacity to previous levels while maintaining the high quality intelligence derived from the supportive populace.

LIMITATIONS OF THE DIRECT ACTION MODEL

The validity of this model and its results are subject to criticism on several bases. First, the model is limited in scope, and attempts to treat the impacts of direct action operations completely independent of the myriad of other operations that are occurring in a counter-insurgency fight. Although correct application of direct action cannot ensure

victory, its misapplication can certainly lead to failure. All elements of power must be synchronized in order to defeat the insurgency. The complexity of the problem requires that the separate elements be evaluated on their own merits, and then properly integrated

Secondly, any attempt to model social interactions with mathematical models must rely on some assumptions. Social models also are notoriously difficult to validate, due in part to a lack of real-world data to compare the results with^{26,27}. Appendix A describes the model in detail, including the mathematical functions and calibration factors used, and offers recommendations for future modifications to the model.

Finally, the model may be difficult to apply directly to real-world insurgency operations. Similar to planning force ratios and Lanchester attrition equations²⁸, the model could provide generalized planning considerations. Despite the limitations in scope, validation, and applicability the model is a potential tool for understanding the impact of direct action operations on the population during a counterinsurgency operation.

RECOMMENDATIONS

Leaders at all levels in an insurgency battle must understand the role of direct action in removing irreconcilable elements of the insurgency who cannot be dissuaded by other means. Recognizing that direct action must play a role, senior leaders must allocate forces and efforts to balance direct action with the myriad of competing missions. Operational commanders, with a view of their entire theater of operations, should make an effort to coordinate direct action operations by articulating their operational concept for direct action to their subordinate leaders. As the model above illustrated, actions in one part of the battlefield can have effects throughout the area of operations. As a result, commanders at the operational level should address the key parameters for direct action. The operational

command is the proper echelon for integration of military effects with the other instruments of influence in an insurgency.

An operational commander can outline his concept for direct action by addressing the key parameters modeled in this study. Although they will likely not be expressed quantitatively, the parameters will provide constraints and restraints to subordinate commanders in their direct action execution²⁹. Following an analysis of the environment, and an internal look at available forces and capabilities, the operational commander should provide initial guidance on the level of Intelligence fidelity and the Threshold he expects for direct action operations. In return, his command must be able to devote sufficient resources to develop targets to the required level of fidelity. Commanders will all realize that there may be exceptions to this guidance that should be re-addressed through the operational commander³⁰.

The operational commander should also consider the relative size of the insurgency when determining how to allocate his limited capacity. Devoting too little capacity to developing intelligence and removing irreconcilable elements can make even a sound operational concept unsuccessful. Conversely, the model suggests there is a point beyond which additional capacity is not beneficial to the effort, and may countermine other efforts at stability by diverting precious resources.

As part of his concept, the operational commander should define a Measure or Performance to see how well the concept is being implemented³¹. A valid MOP may be the percentage of kill/capture operations that result in the capture of an enemy above the stated Threshold. This requires an objective and frank assessment of the true value of a detainee

following debriefings and exploitation. This MOP can indicate the quality of intelligence and identify discrepancies in application of direct action across the area of operations.

Measures of Effectiveness are more difficult, as the objectives of direct action operations are nested within many other operations in counterinsurgency—to reduce levels of violence, improve security, gain popular support, and reinforce the legitimacy of the government. With some compensation for the other ongoing efforts, two potential MOE could be used to assist in assessing the effectiveness of direct action. The level of violence or the number of insurgent attacks may be a valid indicator of effectiveness, as may population surveys³².

The operational commander should plan to re-assess his operational concept at regular intervals, or in response to significant changes in the operating environment. Evaluation of MOP, MOE, and availability of assets could lead to an adjustment in the operational parameters.

CONCLUSION

This study presents a model for understanding the effects of direct action operations on the population during an insurgency. The ability to kill or capture irreconcilable elements of the insurgency is just one small component of a larger diplomatic, informational, military, and economic operation to enhance or maintain the legitimacy of the existing government. The model identified three main parameters that are within the scope of the operational commander's ability to influence. By properly evaluating identified measures of performance and effectiveness, the operational commander can articulate an operational concept for direct action that addresses Intelligence, Threshold, and Capacity to synchronize effects and maximize the prospects for success in the counterinsurgency fight.

APPENDIX A

Mathematical Model

GENERAL

The model used in this study is designed primarily to analyze how a population may react to legitimate or illegitimate kill/capture operations. The model simplifies each individual's complex opinions into a single parameter (Disposition). The model does not address fundamental motivations for these opinions, nor does it differentiate between "right" and "wrong." The limited scope of the study requires the assumption that motivation leads directly to action. The study assumes that if an insurgent has a sufficiently extreme Disposition, he will have sufficient material support and ample opportunity. Similarly for the counter-insurgent, the model assumes that when an irreconcilable insurgent is found, there will be sufficient forces available to conduct the operation to kill or capture him.

The model is lattice-based, and does not allow for geographic mobility. The lattice is externally-bounded, and does not display toroidal interactions (i.e., the left side of the lattice does not "wrap around" to interact with the right side). In addition, the lattice is geographically homogeneous, having no attractors or other influences on the cells within it. Disposition, the key variable in the study, is a continuous variable throughout the scale, but is bounded at the two extremes. Direct social interactions are limited to the cells' Moore neighbors (up to eight adjacent cells), with the ability for extended influence through numerical diffusion during subsequent time steps.

Most significantly, the model has significant stochastic components. Consistent with the uncertainties inherent in warfare and other complex social systems, the counter-insurgent is faced with incomplete information. Because the model contains random elements, multiple runs with the same initial conditions and parameters can lead to different results. When successful parameters are used, the run may be successful for the counter-insurgent in

a large majority of cases. However, there is still the possibility for individual runs to lead to failure due to the stochastic component. As a result, the operating maps shown in the study are based on averages of 25 separate runs.

LITERATURE SURVEY

Various aspects of insurgency warfare have been modeled over the years using system dynamics, deterministic models, agent-based modeling, cellular automata, matrix and lattice models, Monte Carlo approaches, and various hybrid techniques. Efforts have ranged from simple models with a small number of controllable factors to large-scale agent-based, virtual world simulations. This model contributes to the existing literature by modeling the specific relationship between direct action operations and popular support.

Epstein presents an agent-based model of civil violence that relies on individual perceptions of hardship and perceived legitimacy to determine a person's likelihood of becoming an active insurgent³³. The model also incorporates risk aversion as a factor in an agent's decision to contribute to civil violence. Doran³⁴, Lustick³⁵, Moon and Carley³⁶, Kuznar et. al.³⁷, Bulleit and Drewek³⁸, Raczynski³⁹, Warren⁴⁰, Findley and Young⁴¹, and Wheeler⁴² all apply agent-based modeling techniques to various aspects of insurgencies and civil violence. Howell presents a deterministic insurgency model⁴³. Although not developed mathematically, several comprehensive models of insurgencies provide insight into the relationships between the various parameters that influence the progression of an insurgency. Lynn⁴⁴, Baker⁴⁵, and Wendt⁴⁶ all present conceptual frameworks that can be incorporated into future mathematical modeling efforts. Drapeau, Hurley, and Armstrong provide an insurgency framework based on ecological modeling of predator-prey relationships that highlights the competition for the support of the neutral populace⁴⁷. Farley

presents a lattice-based cellular automata model with a stochastic component (similar to the structure presented in this study) that applies evolutionary dynamics to the diffusion of public opinion and the counterinsurgency battle for hearts and minds⁴⁸. A critical component in understanding insurgencies is the evolution of popular opinion and its diffusion through a population. Social models presented by McKeown and Sheehy⁴⁹, Axelrod⁵⁰, and San Miguel et. al.⁵¹ all describe techniques for modeling the spread of opinions and influence through the populace.

MATHEMATICAL MODEL

The user provides the following initial conditions:

Matrix Size: Width (x_{\max}) and height (y_{\max}) of matrix in cells. Results in this study are based on either 10 x 10 or 100 x 100 matrices. While thresholds and converging values differed slightly between the two, the observed trends were consistent for all matrix sizes greater than 5 x 5.

Initial Population Mean (μ): Sampling mean for the Disposition of the starting population (zero to ten). Population mean was varied during this study to portray initial populations with greater or lesser number of extreme insurgents.

Initial Standard Deviation (σ): Sampling standard deviation for the Disposition of the starting population (greater than zero). A standard deviation of four was used consistently in this study.

Initial Intelligence (I): Represents the level of fidelity of the intelligence the commander has based upon the initial population distribution. This represents the initial HUMINT network, baseline technical collection, initial reconnaissance and observation assets, etc. Intelligence is expressed as a percentage which represents the percent of

instances where the perceived Disposition is within ± 1.5 of the true Disposition. For 100% Intelligence, the counter-insurgent will always sample from 6.0-9.0 for a cell with a true Disposition of 7.5. Within this range, the sample is taken from a modified Gaussian (normal) distribution with a mean equal to the true Disposition. For 30% Intelligence, the perceived Disposition will only be within a range of 3.0 centered on the true Disposition in 30% of the cases. At this level, the distribution approaches a uniform distribution.

Threshold (T): User-defined minimum value of perceived Disposition that leads to counter-insurgent action (zero to ten).

Capacity (C): Represents percentage of the population that is effectively covered, observed, or developed by the counter-insurgent during each time step (0 – 100). When multiplied by the matrix size (width times height), Capacity provides the number of cells that are examined during each time step. Cells may be examined more than once during each time step. Therefore, even a Capacity of 100% does not ensure that every cell is examined during each time step.

Time Steps (T_{\max}): The number of steps performed in each run. Each step does not correspond to any specific physical time, but rather is representative of the period during which the counter-insurgent can observe and act in accordance with the specified Capacity. In addition, it represents the frequency with which each cell influences (and is influenced by) its neighbors. In a typical population with reasonable counter-insurgent capacity, each time step may equate to days or weeks. Each run in the study was conducted with 500 time steps, which provided sufficient time for convergence for those runs that led to a near steady-state value of final average Disposition.

Prior to execution, the x_{\max} by y_{\max} matrix is established. Each cell in the matrix is assigned an initial Disposition, $D_{i,j}$. Disposition is randomly sampled from a truncated and re-normalized Gaussian distribution with mean μ and standard deviation σ . The sampling function is provided by the inverse of the following normalized cumulative distribution function:

$$P(x) = \frac{\int_{-\infty}^x \frac{1}{\sigma\sqrt{2\pi}} e^{\left[\frac{-(x-\mu)^2}{2\sigma^2}\right]} dx}{\left[\int_{-\infty}^{10} \frac{1}{\sigma\sqrt{2\pi}} e^{\left[\frac{-(x-\mu)^2}{2\sigma^2}\right]} dx - \int_{-\infty}^0 \frac{1}{\sigma\sqrt{2\pi}} e^{\left[\frac{-(x-\mu)^2}{2\sigma^2}\right]} dx \right]}; \text{ where } 0 \leq x \leq 10$$

An example of a renormalized sampling distribution is shown in Figure A-1.

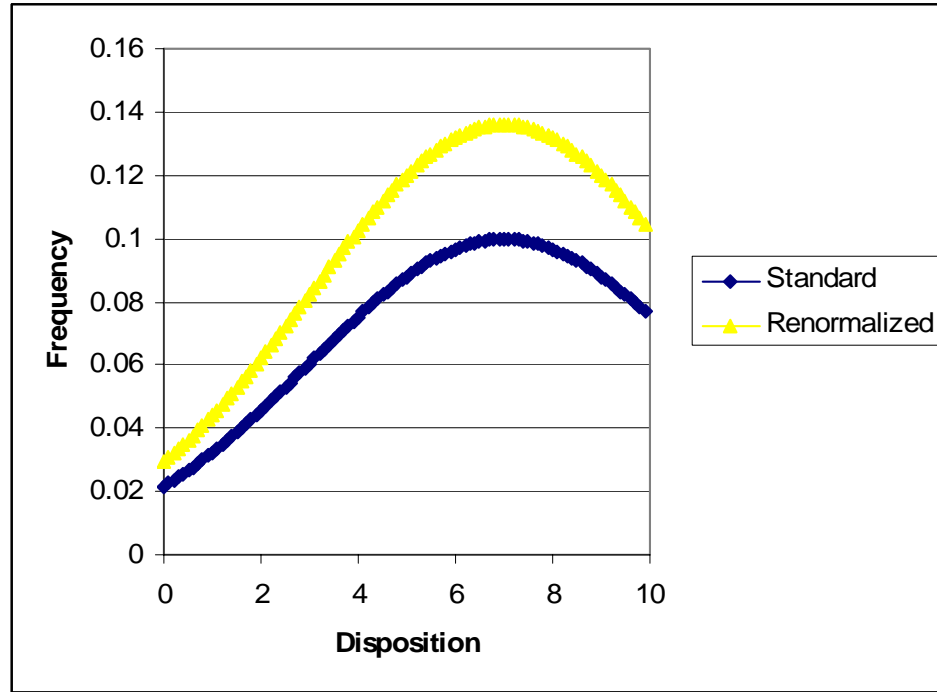


Figure A-1. Sampling distribution for $\mu = 7$, $\sigma=4$.

During each time step, the model chooses one cell at random. The perceived Disposition is computed by generating a Gaussian distribution (truncated and renormalized as above to retain limits of zero and ten) centered on the true value of the Distribution, and

with a standard deviation corresponding to the value of Intelligence. The intelligence-derived standard deviation is related to the Intelligence as shown in Figure A-2. An example of the sampling distribution centered upon a true Disposition of $D=5$ for various levels of Intelligence is shown in Figure A-3.

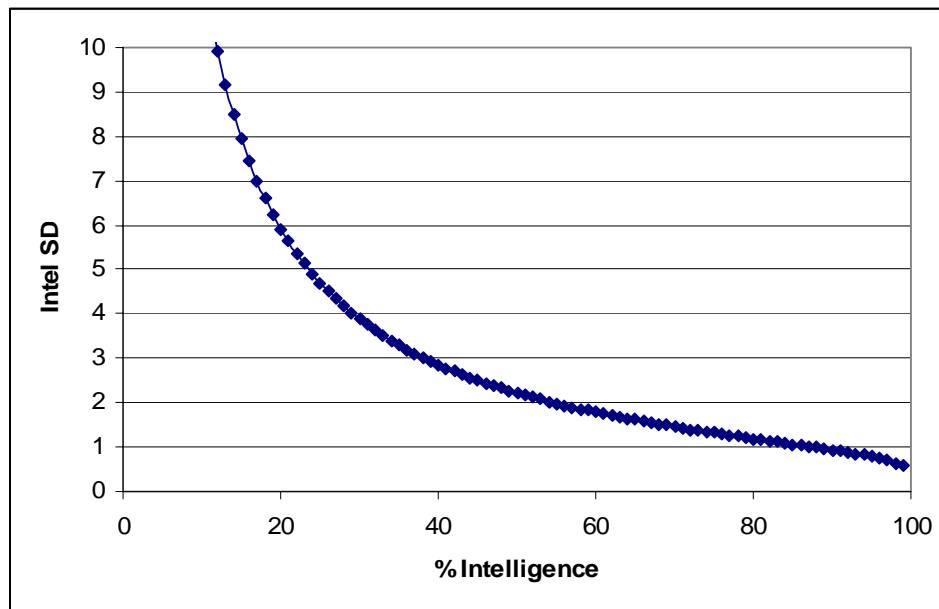


Figure A-2. Standard Deviation used to determine perceived Disposition as a function of Intelligence (expressed in %).

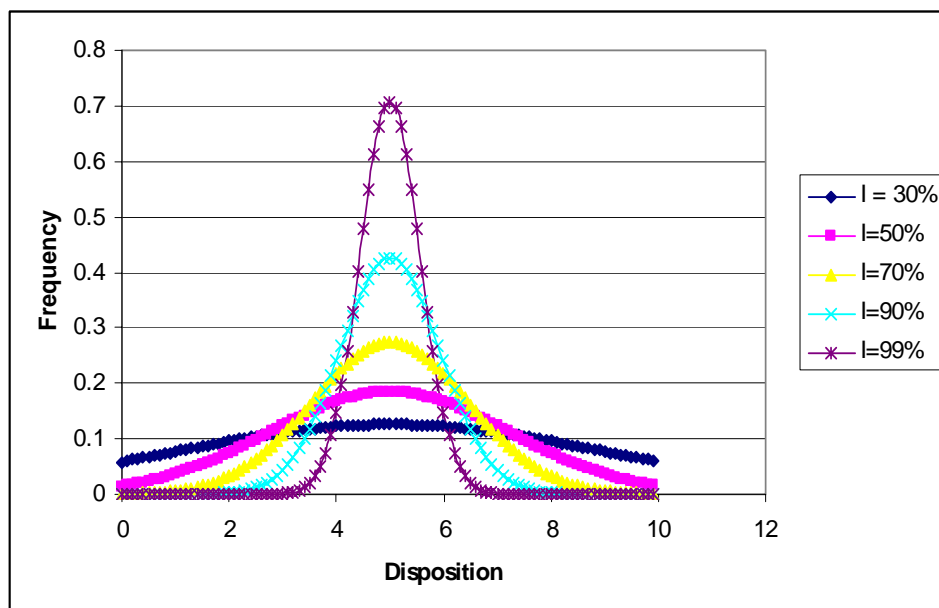


Figure A-3. Sampling distribution to determine perceived Distribution for various levels of Intelligence. ($D = 5.0$).

If the perceived Disposition is greater than the specified Threshold, then the cell is removed from the matrix and replaced by a new randomly determined cell Disposition. This act represents the death or capture of a member of the population.

The model assumes that the act of using military or police forces has an adverse effect on the adjacent cells. This local effect is due in part to the disruption caused by the raid itself, as well as the other raids that were likely conducted unsuccessfully to find the target. It also includes the effect of detaining other associates during the raid, which may be subsequently released (e.g., “collateral damage”). Due to the broad scope of these factors, there is a “penalty” even for the removal of a cell with a very high disposition. The penalty (P_R) is much higher for the removal of a neutral or supportive cell. The penalty is computed by:

$$P_R = P_A + \frac{P_B}{\left[P_C + P_D e^{P_E D_{i,j}} \right]^{P_F}}$$

The model was calibrated and run with $P_A = 0.038561$, $P_B = 1.50$, $P_C = 1.02$, $P_D = 0.0008013$, $P_E = 1.053$, $P_F = 1.265$. The resulting curve is shown in Figure A-4. The curve in Figure A-4 should be adjusted for a particular insurgency based upon indications that associates are more or less impacted by collateral damage. As the effect is described in FM 3-24, the population may become more sensitive to collateral damage as the strength of the insurgency decreases⁵².

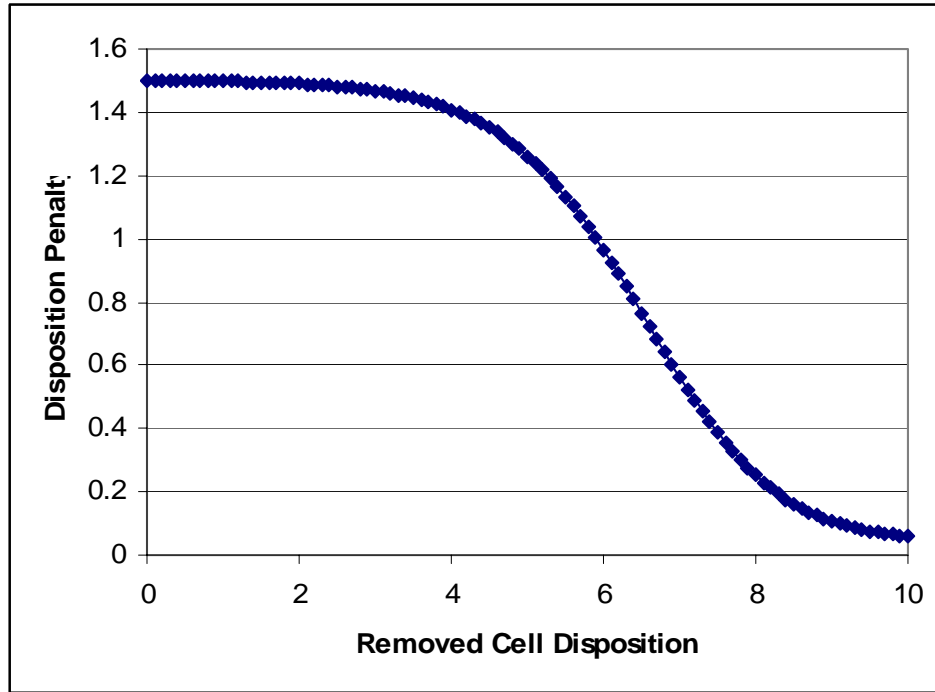


Figure A-4. *Penalty assigned to each neighboring cell following the removal of a cell.*

The cell sampling and removal loop is repeated for $(x_{\max} \times y_{\max} \times C)$ iterations. At the end of the time step, two global effects are calculated. The first effect represents the negative impact on the population resulting from the continued presence of extreme insurgent elements. This is a combination of frustration with the unwillingness or inability of the counter-insurgent to control violence, a loss of legitimacy for the government, as well as a tendency of the population to sway towards the side of the insurgents when they are perceived to be successful⁵³. The model assumes that any cell with a Disposition greater than 5 (exactly neutral) provides some passive or active support that contributes to violence. Higher values of Disposition contribute to violence levels to a greater degree⁵⁴. The level of violence is therefore represented by the sum of the root mean squares of each cell with a Disposition above neutral. This is mathematically analogous to the positive portion of the standard deviation with $D=5$ taken as the mean. This is expressed as:

$$P_d = \sqrt{\sum_{\substack{i,j \\ D > 5}} (D_{ij} - 5)^2} \quad ; \text{ for all cells at lattice } (i,j) \text{ with } D > 5$$

As a global effect, all cells increase their Disposition in proportion to the level of violence experienced. The contribution of existing violence (S) is assumed to be proportional to P_d according to:

$$S = P_d S_1$$

A value of $S_1 = .001$ was used for the results presented in this study. This value should be increased when information indicates that the population is more influenced by the continued presence of violence. It could be rationally predicted that S_1 would tend to increase with time as the population loses their patience with continued governmental inaction.

At the end of each time step, the model also recalculates how the level of Intelligence has changed during the step. Intelligence is presumed to change in proportion to the number of cells with Dispositions below neutral. Similar to the calculation for P_d above, the sum of the root mean squares for all members of the population with $D < 5.0$ is used as an indicator of willingness to provide accurate intelligence to the counter-insurgent (defined as N_d).

$$N_d = \sqrt{\sum_{\substack{i,j \\ D < 5}} (D_{ij} - 5)^2} \quad ; \text{ for all cells at lattice } (i,j) \text{ with } D < 5$$

Based on the root mean square weighting, members with very low Dispositions provide a disproportionately greater amount of accurate intelligence, while those closer to neutral provide very little. The value of Intelligence is then adjusted by comparing the current value of N_d to the value of N_d at the onset of the run (when the baseline Intelligence level was defined):

$$I(t) = I(0) \frac{N_d(t)}{N_d(0)} \quad ; \text{ where } t = \text{time step}$$

The next effect considered is the diffusion of opinion within the population. While there are many popular models for opinion diffusion found in the literature of social modeling, many do not consider the effect of intimidation likely present in an insurgency. Some models assume that influence between two cells is greater if they share some common ground, and other models define a separate property that describes influence. The model proposed here makes some simplifying assumptions. First, it is assumed that a person is more influential if he has more “extreme” views. Secondly, it is assumed that a person is more susceptible to influence if he has a more neutral opinion. This reflects the belief that hard-core extremists will use intimidation and coercion to influence the neutral population. However, their ability to coerce somebody with an equally strong but polar opposite view is less. Finally, the model assumes that each cell only interacts directly with its eight neighbors. The adjustment in Disposition is therefore done in several steps. First, the average value of the (up to) eight neighbors is calculated as D_N :

$$D_N = \frac{1}{N} \sum_{\substack{i=-1 \rightarrow 1 \\ j=-1 \rightarrow 1 \\ |i|+|j| \neq 0}} D_{i,j} \quad ; \text{ where } N = \text{number of adjacent neighbors } (N \leq 8)$$

If D_N is “more extreme” than the central cell’s Disposition (i.e., further from 5.0), then the cell will be influenced. If the average Disposition of the neighbors is less extreme, the central cell will not be influenced. Furthermore, the degree to which the central cell is influenced is proportional to its own “neutrality.” In other words, a cell with $D=5$ will be more heavily influenced by its neighbors than a cell with $D=6$. The degree of influence, r , is calculated as:

$$r = C_1 \left(C_2 - \frac{|D_{i,j} - 5|}{10} \right)$$

And the new value of Disposition is:

$$D_{New} = D_{Old}((1 - r) + D_N r)$$

For the results presented here, $C_1 = C_2 = 0.5$, which means that at most a cell can be influenced up to 25% by its neighbors during a single time step, with influence linearly going to zero when the cell already has an extreme value ($D = 0$, or $D = 10$).

Following the adjustment of these variables to reflect the new state of the population, the model proceeds to the next time step.

CALIBRATION, STABILITY, AND NUMERICAL RESULTS

The mathematical description above obviously involves the choice of several calibration parameters to describe the effects of collateral damage, ongoing violence, intelligence, and mutual influence and intimidation. Changes in these parameters will impact the specific results of any given run, and will clearly change the operating maps presented in the main text. However, the value of the model is in observing the effects of the general trends. These qualitative results remain largely unchanged, regardless of the choices of internal parameters.

As social phenomena such as direct action in insurgencies never occur in a vacuum, it is impossible to quantitatively validate the model⁵⁵. Instead, it is necessary to observe the results for internal consistencies and to compare these observations to accepted social principles. For example, it is well accepted that a government that indiscriminately conducts raids throughout the populace will lose the support of the people (a caveat being the fact that a ruthlessly repressive regime may lose support but maintain order through intimidation of

the populace). The model incorporates this “principle” into calculations and provides consistent results.

The model was calibrated to provide useful data in the moderate (and more realistic) ranges of the operational parameters (Intelligence, Threshold, and Capacity). The model maintains numerical stability at the extremes by preventing such variable as P_d , N_d , and I from going to zero. In these extreme cases, some of the observations are clearly inconsistent with reality. For example, well before the populace become 100% supportive of the insurgency, the government is likely to collapse.

The model also presents the emergence of “tipping points” where the population becomes so committed to the insurgency that there is no operational concept that can be expected to reverse it (roughly $P_d = 8.0$). There is no such observed point favoring the counter-insurgent. Regardless of how supportive the population is of the government, the counter-insurgent can still make bad choices that can lead to failure.

Another interesting observation is that even successful operational concepts can lead to failure. Due to the stochastic character of the model, a counter-insurgent operating well within the green area of Figure 9 could quickly lose the fight. A series of time steps where, by pure chance, the penalties associated with removing cells greatly exceed the benefits can lead to a sharp rise in average Disposition. This can result from actioning a cell with a Disposition below the Threshold (as is statistically possible even with near-perfect Intelligence). This can be compounded when the replacement cell happens to receive a very high initial Disposition. When this happens for one or two time steps, the effects are generally localized and overcome. However, when these circumstances happen for four to five time steps, the rapid increase in average Disposition can be too much to be overcome.

The effect is more pronounced when several of these unfortunate events happen in the same geographical region of the matrix. Figure A-5A shows 25 iterations with $I=75\%$, $T = 7.75$, and $C=25\%$. It is evident that the insurgency converged to a low average Disposition in 23 of the iterations, while a series of “poor choices” caused two of the iterations to show spikes in Disposition. Figure A-5B shows data from the same series of runs. The average and standard deviation of all runs is shown, along with the two deviating runs.

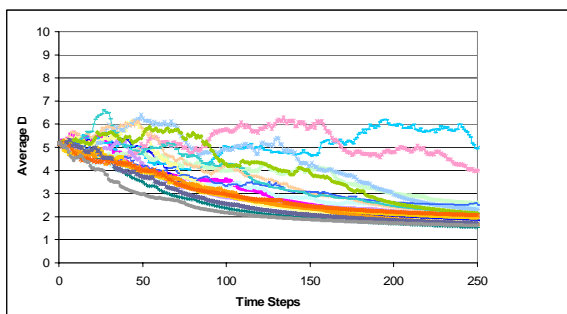


Figure A-5A. Multiple iterations.

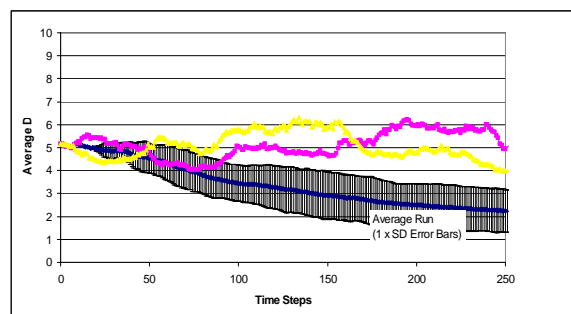


Figure A-5B. Average run with two deviations.

During 23 of the 25 runs, the average Disposition converged to a value near 2.0. However, the stochastic character of the model allowed two runs to deviate significantly, leading to average Dispositions between four and five.

This effect possibly has a real-world analogy. Vigilantly monitoring for these effects can allow the commander to quickly adapt his operational concept to reverse the trend. In particular, these deviations seem to support FM 3-24’s assertion that “Sometimes doing nothing is the best reaction.”⁵⁶ To avoid causing more harm, forcing the model to cease all operations for several time steps following a “spike” generally mitigated this runaway effect.

Another effect observed in the model is the diminished effectiveness of increased Capacity beyond a certain point. As Figure 7 shows, beyond $C=30\%$ there was little net gain in effectiveness. This counterintuitive point is due to the increasingly volatile nature of operations with high Capacity. When Capacity is very high, a significant portion of the

matrix can be actioned in one time step. This produces large swings in average Disposition (as well as swings in Intelligence and violence level), as shown in Figure A-6. It is possible to go from a successful insurgency trajectory into an irrecoverable level of violence in a short time when operating at a high Capacity. In addition, this does not allow time for the cells to socialize with each other, an activity which moderates the swings in Disposition. This high level of operations does not allow a generally supportive populace to influence marginally extremist insurgents, leaving no option for removing them except direct action. This effect could be analogous with FM 3-24's assertion that "sometimes the more force is used, the less effective it is."⁵⁷

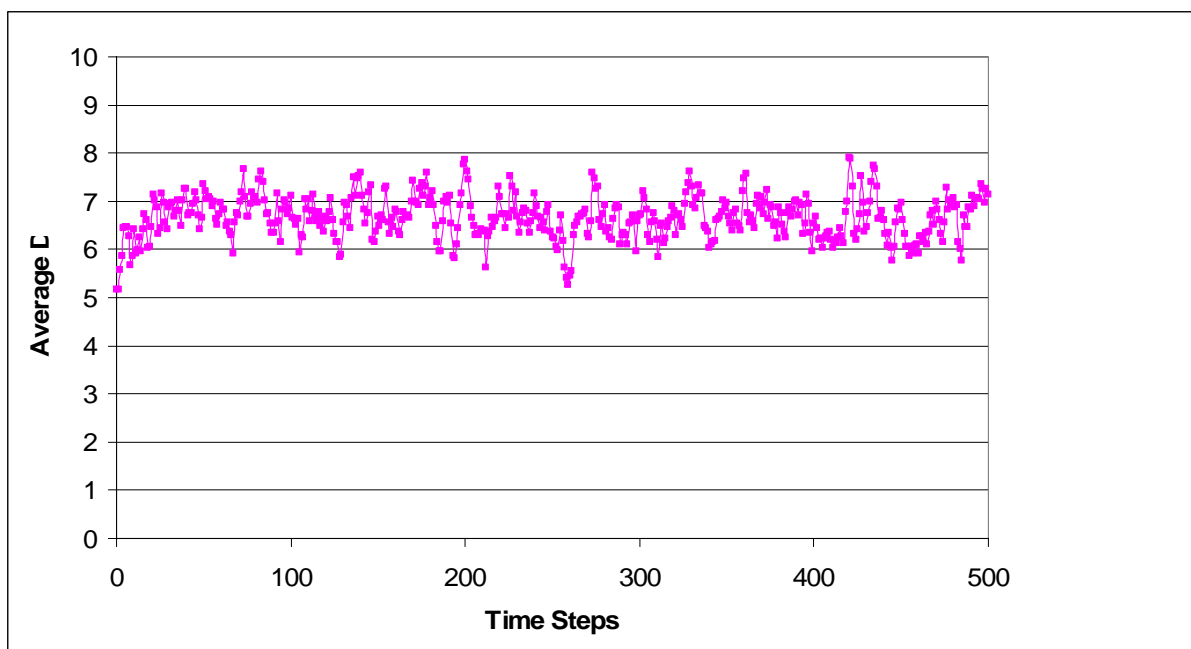


Figure A-6. *Instability observed at high Capacity. (C=90%).*

RECOMMENDATIONS FOR FUTURE WORK

With the current model, the following are recommendations for further study:

- Investigate the conditions that lead to unexpected spikes in Disposition under normally successful conditions. Determine what level of collateral damage is required to cause intractable spikes, and explore the relationship between proximity in time and matrix space.
- Analyze of the role of the initial population distribution in progress of the insurgency. In particular, explore the impact of assuming a bimodal distribution representing an initially polarized population with a small number of neutral cells.
- Further explore the behavior of the system at high levels of Capacity.
- Compare modeled results with population data from a historical insurgency, where effects of indirect measures on the population can be compensated for.
- Compare the stability of the system in response to large step insertions of positive or negative global Disposition changes. Such changes could represent large-scale changes in public perception resulting from political events (e.g., successful elections), large scale insurgent attacks, or successful information campaigns.

Using the current model as a start point, the following are recommendations for enhancements to model other effects:

- Treat Intelligence as a local property of each cell. Instead of a global value of Intelligence, allow each cell to have a different level of fidelity, based in part upon the presence of government supporters in adjacent cells. Allow the commander to weigh Intelligence and perceived Disposition before deciding to act.
- Allow for an increase in local intelligence on associated cells as a result of successful direct action. This would represent the exploitation information derived from actioning a cell with social connections to others.

- Allow the counter-insurgent to develop a region of the matrix and then choose to act against a concentration of irreconcilable insurgents in one time step. This is likely to be more successful for the counter-insurgent, and more accurately represents how enemy cells are currently developed.
- Allow a variation in the number of social connections between cells. This could be done by allowing more than the standard eight Moore neighbors to interact, or by allowing more distant interactions between physically separate concentrations of insurgents.
- Modify the method used for inter-cell socialization to allow for the proposed effect of social influence by the overlap described by Axelrod⁵⁸. The possibility of influence by coercion or intimidation should also be retained.
- Separate the insurgent's Disposition from his participation in violence. Include a resource-based model that would require the insurgents to have the material resources and opportunity before executing operations.
- Manage the counter-insurgent resources to force asset allocation choices between security operations, direct action, civil affairs, and intelligence collection.
- Develop a true agent-based model that allows for agent mobility, multiple and ever-changing social interactions, and a geographical dependence. This model would incorporate elements of several previous studies, with an emphasis on the role of direct action in removing irreconcilable elements. Such a model could explicitly model insurgent recruitment, motivation, and opportunity.

NOTES

1. Throughout the text, “direct action” refers to the use of police or military forces to kill, capture, or detain designated members of the populace. The term does not specify which component conducts the action. Direct action is different from “indirect” methods designed to influence, dissuade, isolate, or coerce insurgent elements, and is distinct from approaches to deny material capability or opportunity for insurgents to operate.
2. John D. Waghelstein and Donald Chisholm, “Analyzing Insurgency,” Joint Military Operations Publication NWC 3099 (Newport, RI: US Naval War College, 2006), 2.
3. Mark Krieger Jr., “We the People are not the Center of Gravity in an Insurgency,” *Military Review*, July-August 2007, 99, <http://usacac.leavenworth.army.mil/CAC/milreview/English/JulAug07/Krieger.pdf/> (accessed 13 April 2008).
4. U.S. Army and U.S. Marine Corps. *Counterinsurgency Field Manual FM 3-24* (Chicago, IL: University of Chicago Press, 2007): 36.
5. Eric P. Wendt. “Strategic Counterinsurgency Modeling,” *Special Warfare Journal* 18, no. 2 (September 2005): 3.
6. The parameter “Disposition” has a value from one to ten to represent where an individual’s loyalty lies upon the continuum shown in Figure 1.
7. Christopher M. Ford, “Speak No Evil: Targeting a Population’s Neutrality to Defeat an Insurgency,” *Parameters* (Summer 2005): 53, <http://www.carlisle.army.mil/usawc/parameters/05summer/ford.pdf/> (accessed 13 April 2008).
8. Alex Ryan and Anne-Marie Grisogono, “Hybrid Complex Adaptive Engineered Systems: A Case Study in Defence,” International Conference on Complex Systems 2006 (Boston: MA: ICCS, June 2006), 7, <http://necsi.org/events/iccs/openconf/author/papers/fl73.doc/> (accessed 13 April 2008).
9. John A. Lynn, “Patterns of Insurgency and Counterinsurgency,” *Military Review* (July-August 2005): 24, <http://www.au.af.mil/au/awc/awcgate/milreview/lynn.pdf/> (accessed 13 April 2008).
10. Wendt, “Strategic Counterinsurgency Modeling,” 5.
11. In this report, the mathematical parameters are referred to by their capitalized names: Intelligence, Threshold, Disposition, and Capacity.
12. “Intelligence” as a mathematical parameter is used in this study to describe the mathematical probability that the counter-insurgent’s perceived value of a cell’s Disposition is close to its true value of Disposition. The relationship between the Intelligence parameter and the sampling distribution is described in Appendix A.
13. Wendt, “Strategic Counterinsurgency Modeling,” 3, referencing the Area of Influence model attributed to Gordon McCormick of the Naval Postgraduate School, Monterey CA.
14. “Capacity” is a mathematical expression on the number of cells sampled during each times step of the model. See Appendix A for a detailed description of Capacity.
15. It is unlikely that a real population is truly randomly arrayed. However, as the model progresses in time, the population begins to group in a manner that more closely represents real social groupings. Appendix A describes some future study to explore the role of the initial population distribution on the outcome of the insurgency.

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16. While in reality targets are not developed at random, the action of the counter-insurgent is somewhat determined by complex information that is not entirely within his control. Improvements to the model to allow for more focused development is included in Appendix A.
17. Jim Baker, "Systems Thinking and Counterinsurgencies," *Parameters* (Winter 2006-2007): 31, <http://www.carlisle.army.mil/usawc/Parameters/06winter/baker.pdf/> (accessed 13 April 2008).
18. David Galula. *Counterinsurgency Warfare Theory and Practice* (New York, NY: Praeger Publishers, 1964), 65.
19. Bard E. O'Neill. *Insurgency and Terrorism: Inside Modern Revolutionary Warfare* (United States: Brassey's Inc.), 82.
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21. Baker, "Systems Thinking," 29.
22. Johnathan D. Farley, "Evolutionary Dynamics of the Insurgency in Iraq: A Mathematical Model of the Battle for Hearts and Minds," *Studies in Conflict and Terrorism* 30, no. 11 (1 November 2007): 959-960, <http://www.ebsco.com/> DOI: 10.1080/10576100701611304 (accessed 13 April 2008).
23. Lynn, "Patterns of Insurgency and Counterinsurgency," 25.
24. U.S. Army and U.S. Marine Corps, *Counterinsurgency Field Manual*, 49.
25. MOP and MOE data are taken from the Dispositions of the cells as they evolve during each particular run. The model tracks the distribution of the population and compares the perceived Dispositions of the removed cells to their true values to determine the MOP.
26. Warren, *Communication, Coordination, and Conflict*, 8.
27. Marcus A. Louie and Kathleen M. Carley, "The Role of Dynamic-Network Multi-Agent Models of Socio-Political Systems in Policy," Report CMU-ISRI-07-102 (Carnegie Mellon University Center for Computational Analysis of Social and Organizational Systems, January 2007), 6-8, <http://www.casos.cs.cmu.edu/publications/papers/CMU-ISRI-07-102.pdf/> (accessed 13 April 2008).
28. Jeffery M. Howell, "Modeling Insurgency Attrition and Population Influence in Irregular Warfare" (master's thesis, Naval Postgraduate School, 2007), 6-8, <http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA469937&Location=U2&doc=GetTRDoc.pdf> (accessed 14 April 2008).
29. Baker, "Systems Thinking," 42.
30. There will always be individual insurgents whose capture or death can have a disproportionately greater effect on the overall insurgency. For these cases, the commander may elect to action targets with a lesser degree of Intelligence. The framework in this study outlines some of the factors that may weigh in his risk-versus-gain decision to do so.
31. Baker, "Systems Thinking," 39.
32. While population surveys conducted by the military, media, or government may be biased, they are likely internally consistent. Because there is no reliable means to measure legitimacy or disposition, observable MOE such as surveys are essential.

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47. Mark D. Drapeau, Peyton C. Hurley, and Robert E. Armstrong, "So Many Zebras, So Little Time: Ecological Models and Counterinsurgency Operations," *Defense Horizons*, no. 62 (February 2008), http://www.ndu.edu/ctnsp/defense_horizons/DH%2062.pdf (accessed 14 April 2008).
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